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3D PRINTING IN POPULARIZATION OF SCIENCE

3D TISK V POPULARIZACI VĚDY

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3D tisk v popularizaci vědy

POKYNY PRO VYPRACOVÁNÍ:

Cílem práce je popsat principy 3D tisku a navrhnout jakým způsobem je možné využít 3D tisku pro popularizaci vědy.

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Cano, L. M. (2015). 3D Printing: A Powerful New Curriculum Tool for Your School Library. USA: Libraries Unlimited. - Saras, A. (2019). 3D Printing Made Simple: Exciting & Innovative Technology. BPB Publications. - Boozarjomehri, K. (2017). 3D Printing at School and Makerspaces: Project Learning with 3D Printing. Cavendish Square Publishing. - Santos, I. M., Ali, N., & Areepattamannil, S. (2018). Interdisciplinary and International Perspectives on 3D Printing in Education: Advances in Educational Technologies and Instructional Design (2326-8905). IGI Global.

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Abstract

The Bachelor's thesis deals primarily with the use of 3D printing by a public which is not acquainted with the technology. The work is divided into two main parts – the first mentioning the theory and the second part proposing practical activities. In the first part, the terminology in connection with 3D printing is defined, the process of 3D printing is determined, and the historical evolution of 3D printing processes is outlined. Except for the 3D printing itself, the process of 3D printable model creation, as well as, the possibilities in the use of 3D printers are described in the first part of the thesis. Additionally, 3D printing pens are depicted. In the second part, the practical part, specific activities for children with the use of 3D printing pens or 3D modelling programs are proposed. All of the activities contain expected time duration, age group and the main objective.

Keywords

3D printing, 3D modelling, popularization of science, 3D pen, Tinkercad, activities for children

Abstrakt

Tato bakalářská práce se zabývá především využitím 3D tisku veřejností, která není s touto technologií seznámena. Práce je rozdělena do dvou hlavních částí – první část uvádí teorii a druhá část předkládá praktické aktivity. V první části je definovaná terminologie spojená s 3D tiskem, je stanoven proces 3D tisku, a je nastíněn historický vývoj procesů 3D tisku. Kromě samotného 3D tisku je v první části této práce popsán i proces tvorby 3D tisknutelného modelu a také jsou popsány možnosti využití 3D tiskáren. Kromě již uvedeného jsou také popsána 3D tisková pera. V druhé části, praktické části, jsou navrženy konkrétní aktivity pro děti s využitím 3D tiskových per nebo 3D modelovacích programů. Veškeré tyto aktivity obsahují očekávanou délku trvání, věkovou skupinu a hlavní cíl.

Klíčová slova

3D tisk, 3D modelování, popularizace vědy, 3D pero, Tinkercad, aktivity pro děti

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Prohlášení

„Prohlašuji, že svou bakalářskou práci na téma 3D tisk v popularizaci vědy jsem vypracovala samostatně pod vedením vedoucího bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

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V Brně dne ....   …..

Klára Kubíčková

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Contents

1. Introduction

Modern technologies advance rapidly and 3D printing is one of the most visible among other disciplines nowadays. The employment of 3D printing was primarily associated with mechanical engineering and especially with large companies. Although, in recent years, it became more known to the wide public due to its popularity in diverse contexts of modern technologies. As an example, the medical field should be mentioned in connection with technological advancements where 3D printers can be highly beneficial (printing of prosthetics, bioprinting of tissues). Or 3D printing can be presented even in the form of a curiosity (3D printing with chocolate, movie properties).

In the present day, 3D printers are identified as commonly used in a broad range of fields. Modern 3D printers have become easily affordable and more accessible even for a wide public. The possibilities of creation with the help of 3D printing are endless. The 3D printing creation is bound not only to 3D printers, but also more modern devices, called 3D pens, which may be used as well. The focus of this thesis will be most preferably put onto the use of 3D printing with the purpose of broadening the knowledge of the general audience. The popularization of science itself is a wide topic, thus, only its specific parts which can be connected with 3D printing practically will be discussed, such as the feasible approaches to the utilization of 3D printing in the science popularization facilities.

This bachelor's thesis will consist of two main parts – a theoretical part and a practical part. In the theoretical part the term 3D printing will be defined, printing principles described and a brief history explained. Additionally, 3D printing pens will be described and approaches to the creation of models for 3D printing. Finally, examples of the use of 3D printing in educational and popularisation institutions will be provided.

In the practical part of the thesis, potentially employable approaches for the use of 3D printing, as in a form of 3D modelling and printing with 3D pens, for children activities will be proposed. The practical part of this work will be focused more on working with 3D printing pens and 3D modelling programmes in a group of children. These activities should be planned with the aim of educating, uncovering, and disclosing the technology of 3D printing as well as sciences and finally inspiring and motivating for further discoveries.

2. History and principles of 3D printing

2.1 Defining the term

The term **Three-Dimensional printing** (further on referred to as 3D printing) is defined by the Techopedia (n.d.) as *"...a manufacturing process through which three-dimensional (3D) solid objects are created."* This means that physical three-dimensional objects can be created by various processes where layers are stratified in either liquid, solid or powder-based form.

While searching for the term 3D printing, other terms might appear, for example, rapid prototyping or additive manufacturing. The term **Rapid Prototyping technology** (RP) was used in the 1980s for a technology of stereolithography (SLA), this technology is further discussed in the paragraph concerning with the topic of history. (Chua & Leong, 2017) Even though 3D printing is only one part of the whole process, it was used instead of RP later. **Additive Manufacturing** (AM) as it is specified by Joseph Flynt (n.d.) *"...involves the whole process of making 3D solid objects from computer-generated files, or digital files."* The term 3D printing is often used for AM even though 3D printing and AM do not convey the exact same meaning due to 3D printing being only a part of the whole procedure of AM. Regardless, 3D printing is often used as a synonym for AM by the general public.

2.2 Printing principles

In this paragraph, the general and fundamental approach to the whole process of AM is described. It does not solely describe the part of printing an object.

The first step of the process can be done either by modelling with the help of a CAD/CAM system or by 3D scanning of the model. For this step, it is highly important to have the model (data) specified not only by the outside parameters but also by the parameters inside the model. The model can have hollow parts, but its boundaries must be specified in advance. Support structures should be generated during this step as well. Whether the support for the model proves to be crucial or not can be estimated by the 45° angle rule. This rule is defined in book 3D Printing and additive manufacturing by Chua & Leong (2017) as *"any overhanging parts having less than 45° angle from the horizontal axis needs its support"* (p. 27) or it can be estimated by the type of the printing technique itself

(Selective Laser Sintering does not need additive support as its technique serves as a support itself).

Once the model is designed, it is necessary to convert its format into the .STL file format (this format uses triangles and other simple polygons for approximation of the surfaces).

In the next step a computer program analyses the .STL file and divides the model into thin cross-sections. Then follows the process of printing itself.

Depending on the input form of material, the printer either glues thin laminations together with adhesives or solidifies cross-sections of liquids or powders. By the form of its initial material, three 3D printer categor**ies** can be classified: liquid-based, solid-based and powder-based. In a liquid-based method, the initial liquid is solidified into the solid-state. Examples of these printing types are *3D Systems' SLA* (stereolithography) or *Stratasys' Polyjet*, *3D Systems' Multijet Printing* (MJP) and others. The powder-based method might be confused with a solid-based one, however, it is considered that the input powder for this method is in a grain-like form. Examples of this printing type can be *3D Systems' SLS* (Selective Laser Sintering), *Arcam's Electron Beam Melting* (EBM) or *3D Systems' ColorJet Printing* (CJP). For the last method, which is solid-based 3D printing, any solid form (wires, laminates, rolls) of input material can be used. In this category, *Stratasys' FDM* (Fused Deposition Modeling) or *Mcor Technologies' SDL* could be mentioned. (Chua & Leong, 2017)

After the physical model is fully printed, manual operations are still needed before the model is fully completed. Mostly excess material removal (removal of supports, excess powder) is necessary.

2.3 History

The origin of 3D printing dates back to the second half of the twentieth century. In the year 1986, Charles W. Hull came with the idea of stereolithography and the first **stereolithography** printer SLA-1 was launched for commercial purposes by 3D Systems company in the 1987. (Our Story, n.d.) Since the introduction of this first printer, many others have tried to realize the idea of 3D printing. With the increase in competitors, the development of new 3D printing technologies was rapidly accelerated.

The same year as the printer SLA-1 was introduced, Michael Feygin presented another technique called **Laminated Object Manufacturing** (LOM). With this technique thin layers are laminated together by heat and pressure and afterwards, they are cut into the desired shape either by laser or blade. Another well-known technique is **Selective Laser Sintering** (SLS), this technique was patented in Austin in the year 1988. Later in 1989 S. Scott Crump, co-founder of Stratasys, invented and patented **Fused Deposition Modeling** (FDM) where thermoplastic is used. Another important year is 1993 when MIT got patented **3DP** (3-Dimensional Printing) where thin layers of powdered material are hardened together by a binding agent. For this technology no support structures are necessary. Later Z Corporation bought 3DP patent which lead to further improvements of this printing type. (Kocovic, 2017)

Figure 1. 3D Systems 3D printer the SLA-1(Retrieved from: https://www.3dsystems.com/)

In 1996, the term 3D printer was officially used for the first time, when 3D Systems sold its first 3D Printer *Actua 2100*. Previously the machines themselves were called stereolithography systems. The technology used in this type of printers was based on a mechanism similar to the inkjet printers. (Kalaskar, 2017)

Since the beginning of the 21st century, the development of 3D printers has advanced. Simultaneously, various brands of 3D printers were presented to the world. Nonetheless, the milestone of 3D printers arose with **Rep Rap**. The philosophy behind this project was to create a 3D printer, which would recreate itself. The main idea was to create accessible 3D printers for the wide public. This idea was supported by the fact that the Rep Rap project was licensed with GNU GPL license. This license allowed anyone to print the whole 3D printer or at least print its parts as it was open-source. With this initiative commenced the era of low-cost personal 3D printers. Besides, the rapid growth was caused by online communities sharing open-source 3D printer design files. (RepRap, 2019)

In 2014 many AM patents expired, which led to an extension of a variety of low-cost printers. (Hornick & Bhushan, 2016)

2.4 Basic printing technologies

The basic printing technologies mentioned briefly in the chapter of history are presented in more detail in this chapter. Table of basic printing technologies provides a variety of well-arranged printing techniques described by their full name, abbreviation used, a material used and its principle of 3D printing.

Technology	**Abbreviation**	**Material**	**Principle**
Stereolithography	SLA	liquid-based	Photopolymerization
MutiJet Modeling	MJM	liquid-based	Material jetting
Solid Ground Curing	SGC	liquid-based	Photopolymerization
Selective Laser Sintering	SLS	powder-based	Powder binding
Laminated Object Manufacturing	LOM	solid-based	Sheet lamination
Fused Deposition Modeling	FDM	solid-based	Extrusion printing

Table 1. Table of basic printing technologies

Compiled from the aforementioned data (Kratochvílová, 2015) and (Chua & Leong, 2017)

3. 3D printing pens

The 3D pen is a special type of a pen which prints in three dimensions. Its principle is similar to the standard 3D printing, however with the 3D pen the movement of the tool itself is controlled by the user's hand, instead of the software driving the printhead into the motion. This means, no software is needed for designing models with 3D pens. (Kratochvílová, 2015)

Occasionally, 3D pens are compared to glue guns. In comparison to the glue guns, where during its use the melted glue takes time to harden, in case of the 3D pen, the melted filament cools down and solidifies as quick as it is pushed through the nozzle. (Flynt, 2017)

3D pen offers a wide range of usages as Starodubtsev (n.d.) claims in the pen for three-dimensional printing patent that *"Images or objects produced with a 3D pen can be created as flat forms that can be peeled from a piece of paper, as freestyle 3D objects, or as separate parts ready to be joined together."*

3.1 Principle of 3D pens

Two basic types of 3D pen exist - cold 3D pen and hot 3D pen. Depending on the type of 3D pen, a specific type of material has to be used and the working principle differs. (Soldatov, 2017)

3.1.1 The cold 3D pen

For the cold type of 3D pens, principles similar to the ones used in SLA 3D printers are used. For this type of pens, material similar to ink which is called photopolymer or photosensitive resin is used. When exposed to light, the material itself solidifies instantly. This means that instead of heating and solidification when cooled in the air, the chemical process is used for solidification. This type of pen reduces the possibility of burns when in contact with skin. ("pick3dprinter.com", n.d.)

3.1.2 The hot 3D pen

The other option of 3D pen operation is based on the FDM 3D printing technology. For this type of 3D printing filaments heated inside the pen are used. Depending on the type of 3D pen the temperatures used during the process may vary. Once the filament is heated to the desired temperature and melted, it can be pushed out of the nozzle. The 3D shapes can be created by an instant solidifying of the flowing plastic as it cools down quickly. (Mashambanhaka, 2019)

The most common types of filament materials for 3D hot pens are **ABS** (Acrylonitrile Butadiene Styrene) and **PLA** (Poly Lactic Acid). Additionally, Flynt states that possible materials for 3D pens can be: *"…PVA (Polyvinyl Alcohol), polyamide (nylon), glass filled polyamide, polycarbonate (PC), and high density polyethylene (HDPE)."* (Flynt, 2017) Furthermore, it is stated on the website of 3Doodler (which is a brand of 3D pens) that even metals, wood fibres or flexy (a rubberized plastic) can be used as the input for 3D pens. ("3Doodler: What is a 3D Pen?", n.d.)

ABS (Acrylonitrile Butadiene Styrene)

ABS is frequently used due to its low price, good availability, impact resistance, stiffness and strength. (Izdebska & Thomas, 2016) However, the major disadvantage of this material is the higher temperature needed for melting. During the process of melting the plastic produces vapours which can cause irritation, (Wojtyła et al., 2017) thus the workplace needs to be well ventilated.

PLA (Poly Lactic Acid)

PLA is a more ecological alternative of filaments as it is considered a recyclable thermoplastic. (Rasal et al., 2010) The filament may not be polluting the environment to such extent considering its possible biodegradability. (Gupta et al., 2007) Moreover, there are no fumes produced during the process of working with this material, as its melting point is lower. (Wojtyła et al., 2017) Unfortunately, the cooling down process is slower in comparison to ABS, which can lead to increased fragility.

4. Creation of models for 3D printing

The first step in the process towards 3D printing, as it was stated in the printing principles chapter, can be either modelling with the help of a CAD/CAM system, 3D scanning of the object or the use of publicly available 3D models.

4.1 3D modelling software

For 3D printers a huge variety of usable modelling software is available. Some of this software is more suitable for 3D printing, others can be aimed at the design of video games or animations. In this chapter, the basic principles of 3D modelling will be described as well as possibilities which are most suitable for the purpose of popularization.

4.1.1 Theory

Direct modelling of a physical object from various materials has been known for a long time. However, with the improvement of technology, a significant amount of modelling is nowadays done at first with the help of modelling software, to make sure that no expensive material is wasted. The possibility of viewing the final object in 3D prior to the printing can save time and material as well as reduce all possible errors. These digital models are easily changeable and any modification can be done without any impact on the model. The steps taken in the process of creation can be reverted, so the parts can be placed back to their previous place without any problem, which would not be possible with a physical model. (Zizka, 2014)

There is not only one possible approach towards 3D modelling, therefore, the main approaches to the object modelling will be discussed here: solid modelling, polygonal modelling, parametric modelling (sometimes also called curve modelling), digital sculpting.

4.1.1.a. Solid modelling

Solid modelling is an approach of 3D modelling, which uses simple shapes (so-called primitives) and manipulates them to create new and more complicated shapes.

Solid modelling method is also frequently called **CSG** (constructive solid modelling). (Stroud, 2006) According to Stroud (2006), *"CSG represents objects as trees of the point-set primitives, combined with the three Boolean operators: ADD, SUBTRACT, and INTERSECT."*(p. 5)

The traditional primitive shapes as described in Handbook of Discrete and Computational Geometry are block, sphere, cylinder, cone and torus. (Goodman et al., 2017) Nowadays, the predefined shapes in any modelling program can be more diverse and complicated. For example, TinkerCAD provides even 3D letters in its primary shapes. (Tinkercad, n.d.)

This modelling technique provides many advantages for novice users. The main advantage can be that this type of software commonly deals with so-called water tightness or manifold integrity, which is an important property for 3D printing designated models. According to Soloman (2020) *"A 3D object model is watertight when the printer can tell the inside from the outside of the model. If you filled up the model with water, no water would drain out."* (p. 257)

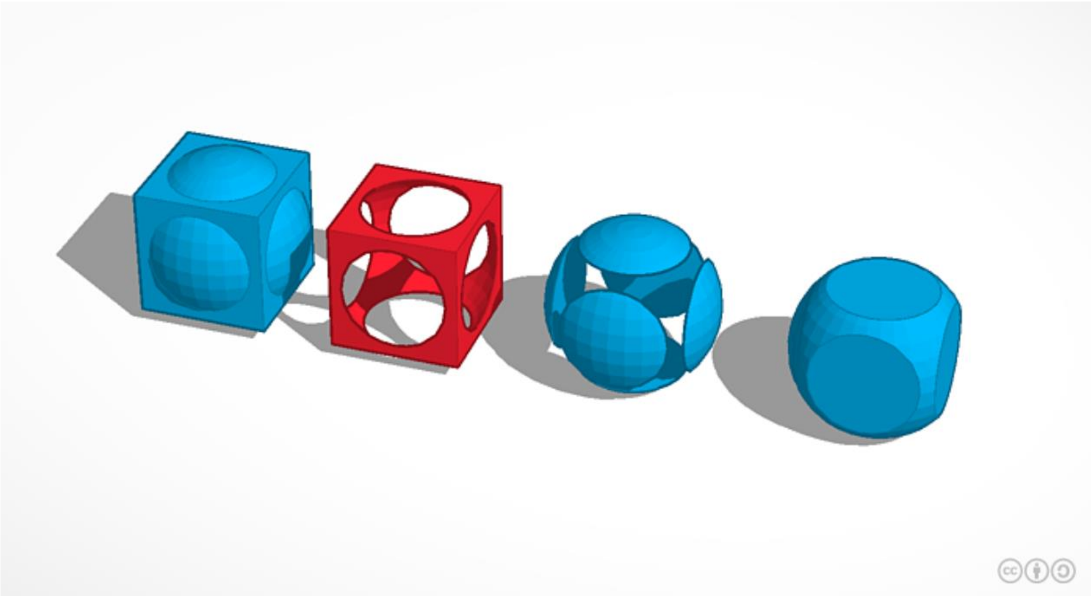

Figure 2. Boolean operation in 3D created by Matthew Paproski (Retrieved from: https://www.tinkercad.com/things/5L9mCHMdcCT-matthew-paproski-boolean-operations)

4.1.1.b. Polygonal modelling

Merriam-webster (n.d.) defines polygon as *"a closed plane figure bounded by straight lines"*. Polygonal technique of 3D modelling uses a group of vertices and edges that form polygons. Polygons aligned together in the form of a mesh then defines the surface of the model. This approach to 3D modelling is more complicated, and for the possibility of 3D printing of the model, additional work is required. (Russo, 2006) Learning to work with this kind of program is more complicated, on the other hand, it offers a higher amount of precision and more amount of possible control. (Marinčić, Hovestadt & Bühlmann, 2019) For possible 3D printing of the model, any missing polygons and any vertices which are disconnected must be found and repaired before the process of printing. Additionally, the mesh created has to be verified for manifold integrity (if the mash is water tight). (Make: Ultimate Guide to 3D Printing, 2012) This kind of modelling is used as Rossignac (2007) states *"as primary representations of solids in most Virtual Reality, Animation, Entertainment, Architecture, and other applications."* (p. 7)

Examples of this type of modelling are programs such as 3ds Max or Maya**.** (Russo, 2006)

4.1.1.c. Parametric modelling

Parametric modelling, as the name indicates, uses parametric equations in modelling. Merriam-Webster (n.d.) defines parametric equations as *"any of a set of equations that express the coordinates of the points of a curve as functions of one parameter or that express the coordinates of the points of a surface as functions of two parameters."* This modelling can be described as modelling based on writing simple programs describing how to combine shapes together. (Fu, 2018) Thus, some preceding knowledge is expected for working with these programs. As well as the learning process would be more complicated than for previously mentioned techniques. Woodbury, Williamson & Beesley (2011) claim that parametric modelling systems *"...require considerable effort to learn and working with them is very different from working with other systems."* (p. 2)

This kind of modelling is according to Soloman (2020) *" ... utilized by engineers and architects because the file encompasses more precise dimensions, relationships, and can include design history"*. (p. 273) As an example of this approach can be mentioned OpenSCAD and FreeCAD. (Machado et al., 2019)

4.1.1.d. Digital sculpting

Digital sculpting is a modelling process similar to traditional sculpting. Mongeon (2015) claims that in digital sculpting *"...there are tools to mimic each traditional tool."* (p. 108) Additionally, Vaughan states that digital sculpting is the closest digital modelling approach to the traditional sculpting. Digital sculpting is performed on the top of primitive shape, which can be formed into the desired shape by the sculpting tools. (Vaughan, c2012) In the case of digital sculpting, it is more focused on the additive process than on the subtractive one. (Mongeon, 2015) Detailed models with clear-cut structure and precise texture can be achieved by this modelling technique. The quality of the final product is based on the number of polygons. (Soloman, 2020) Digital sculpting software is for instance: ZBrush, Sculptris, Mudbox. (Mongeon, 2015)

4.1.2 3D modelling software

From previously stated theory we can understand that not all types of software serve the purpose of creating a model for 3D printing equally. Additionally, not every software has desirable properties for the use of wide public. The main objective should be intuitiveness, accessibility, minimal required previous knowledge, illustrative nature, additionally, the lower the price the better.

Software	Difficulty level	Platform	File Formats
TinkerCAD	beginner	Browser	OBJ, SVG, STL, PART
Leopoly	beginner	Browser	OBJ, STL
SculptGL	beginner	Browser, Windows	OBJ, PLY, SGL, STL
SketchUp Free	beginner	Browser	SKP, STL, PNG
Vectary	Intermediate	Browser	OBJ, DAE, USDZ, GLB, gITF, STL
Clara.io	Intermediate	Browser	FBX, Collada, STL, OBJ, Three.JS, STEP, 3DS, Blender and more
BlocksCAD	Intermediate	Browser	DXF, OFF, STL
3D Slash	beginner	Windows, Mac, Linux, Raspberry Pi or Browser	3dslash, OBJ, STL, FBX, Collada, gITF
FreeCAD	beginner	Windows, Mac, Linux	STEP, IGES, OBJ, STL, DXF, SVG, DAE and more
Wings 3D	beginner	Windows, Mac, Linux	3DS, FBX, OBJ, DAE, LWO, WRL, RWX, STL, XML
Meshmixer	Intermediate	Windows, Mac, Linux	AMF, MIX, OBJ, OFF, STL, 3MF
Sculptris	Intermediate	Windows, Mac	OBJ, GOZ
Daz Studio	Intermediate	Windows, macOS	OBJ, FBX, DAE, DAZ
Magica Voxel	Intermediate	Windows, Mac	2d, ISO, MC, OBJ, PLY, qb slab, VOX, XRAW
MakeHuman	Intermediate	Windows, Mac, Linux	DAE, FBX, OBJ, STL

Table 2. Free 3D modelling software - data combination from two sources: (All3DP, 2020) and (von Übel, 2020)

In this table, we can see that a huge variety of 3D modelling software is currently available for free. However, for the purpose of 3D printing not every program from the aforementioned table is suitable. Some of those programs are, simply put, not intended for 3D printing as they require additional work afterwards the modelling process.

4.2 3D scanning

3D scanning can be recognized as another approach for turning a physical 3D object into the digital representation of the object. With this possibility, the scanned object can be easily modified in a program and further printed in the improved modified shape. Additionally, 3D scanning can be used as an approach to 3D modelling, where the desired 3D model already exists and needs only simple modifications.

4.2.1 3D scanners

For 3D scanning, several techniques exist which are used by the 3D scanner types. The most basic and practical categorisation of 3D scanners is by the technology of scanning into: laser triangulation 3D scanning technology, structured light 3D scanning technology, photogrammetry and contact-based 3D scanning technology. (Arrighi, 2020)

5. Possibilities in the use of 3D printers and 3D pens

Many years have passed since the invention of 3D printing. The 3D printers were supposed to shift the mass manufacturing towards the personalization and customization manufacturing. (Saras, 2018) 3D printers are still commonly used in industries, mostly for prototype printing. To provide some examples of printing in industries, 3D printing is commonly used in aerospace industry (flight instruments, zero-G 3D printing), automotive industry (fully 3D printed car), jewellery industry, coin industry, architecture (multiple models), fashion and textile, marine and offshore, medical and bioengineering applications and many others. (Chua & Leong, 2017) Regarding its innovative nature, 3D printing is nowadays used for even less expected purposes such as gastronomy, where specific elements can be printed, for example, sugary culinary creations. (CHEFJET 3D PRINTER, n.d.) This thesis is focused on 3D printing in popularization of science, as can be derived from its name. How and where can 3D printers be used for popularization purposes will be discussed in the following paragraphs.

5.1 The popularization of the technology of 3D printing

In the context of popularization of science connected with 3D printing, we can discuss popularization of the technology behind 3D printing. In this case, it means focusing solely on popularizing the technology of 3D printing. Or we can use the technology of 3D printing for the popularization of sciences altogether. Primarily, how the accessibility of 3D printing was helped by Rep Rap. Recently, very beneficial for the popularization was the engagement of 3D printing in Marker Fairs or Fab Labs (digital fabrication laboratories). (“FabLabs”, n.d.)

5.1.1 Rep Rap

This paragraph will be focused on how Rep Rap helps spreading the knowledge of 3D printing among the public. On the RepRap official webpage, it is stated that: *“RepRap is humanity's first general-purpose self-replicating manufacturing machine.”* (RepRap, 2019)

RepRap and its community project were briefly mentioned within the chapter of the history of 3D printing as the milestone in 3D printing, which led to the expansion of cheaper 3D printers. The RepRap printers are well known for the fact that they can partially self-replicate by printing the plastic parts. By this process, its own kits for further assembling are created. The possibility of printing other, non-plastic parts, such as step motor or electronic components, is one of the main future objectives to achieve fully self-replicating 3D printers. At the moment they have to be produced independently. However, the possibility of self-replication caused RepRap to be the most widely used 3D printer globally among the Maker Community. (RepRap, 2019)

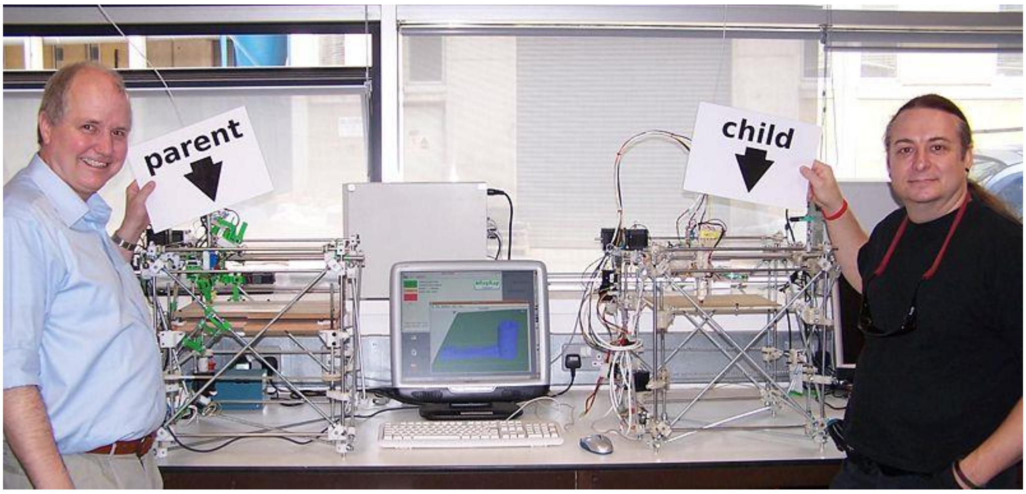

Figure 3. Adrian Bowyer and Vik Olliver with parent and child RepRap machines (Retrieved from: https://reprap.org/wiki/File:Pc-va.jpg)

Encouragement for the evolution of the primary 3D printers led to publishing a huge range of design modifications. The designs differ by the method or material used for printing as well as in the size or shape. The webpage RepRap.org provides access to all of the designs. Moreover, the designs produced by the community project RepRap, are published under the GNU GPL license. Which means it serves as a sort of an open-source hardware platform. (RepRap, 2019)

The project webpage, which is available to a wide public and translated into many languages, contains important knowledge, as well as is extending the common knowledge about 3D printing possibilities. In a way, this partially leads to the popularization of the technology of 3D printing. The process of printer assembly can be further taken as an educational experience. (RepRap, 2019)

5.2 Popularization of Science

5.2.1 History of science popularization

The importance of science and technology for society grows rapidly as people face a considerable amount of technological inventions on a daily basis. Popularization, more precisely the transitive verb popularize is defined by Merriam-Webster (n.d.) as *"to present in generally understandable or interesting form"*. (Merriam-Webster, n.d.) From this definition, the meaning of science popularization can be derived as a form of spreading knowledge, where experts in a specific scientific field share their professional knowledge in an easily approachable form for the uninterested general public.

The approach towards science varied through centuries. Most importantly during the Age of Enlightenment (17.-18. century), the emphasis was put on the legitimization of science. The focus shift on the act of making science popular or approachable appeared later. Approaching contemporary time, the importance of scientific education became more emphasized. (Massarani & Moreira, 2004) The Space Race, one of the main turning points for the popularization, is the moment when science became quasi-political during the 20th century. (Shinn & Whitley, 1986) Even though it might not have been its initial purpose, this event helped the popularization of science considerably.

Science can be spread and popularized via various institutions or in diverse forms. To provide some examples of popularization of science, it can carry a form of a hand-on experiment, can be spread via a television program, or can be conveyed in a spoken form etc. (Massarani & Moreira, 2004)

5.2.2 Popularization of science via 3D printing

The popularization of science does not have to be focused exclusively on hard sciences such as engineering, it can be focused on soft sciences such as history or archaeology as well. To popularize specific fields of science various methods of 3D printing usage can be concerned. The method commonly seen is the printing of an unexpected object. It can be unforeseen in its size (making it gigantic, tiny or even in its respective scale in case of objects which are not common) or in creation of unexpected materials (printing with chocolate, material for printing recycled from dumped waste). The 3D printing in popularization of science in the school environment can be achieved via printing teaching aids. Use of 3D printers in learning processes is possible in various forms as a tool for extending vocabulary, supporting creativity when creating covers for books, creation of cell models all the more by designing own simple machines. These possibilities will be discussed in the following subchapters on existent examples.

Mammoth skeleton 3D printed in a scale

Efforts to preserve and show skeletons of extinct creatures are undergone by numerous museums. For example, in the Natural History Museum in London, a replica of a dinosaur skull was 3D printed. (Pavid, 2018) However, one of the biggest 3D projects in the world, manufacturing a whole mammoth skeleton in its life-size is by a firm in Lier, Belgium. The 3D printers had to be specifically designed for this purpose with its size of 210x70x80cm. (Sehmke, 2018)

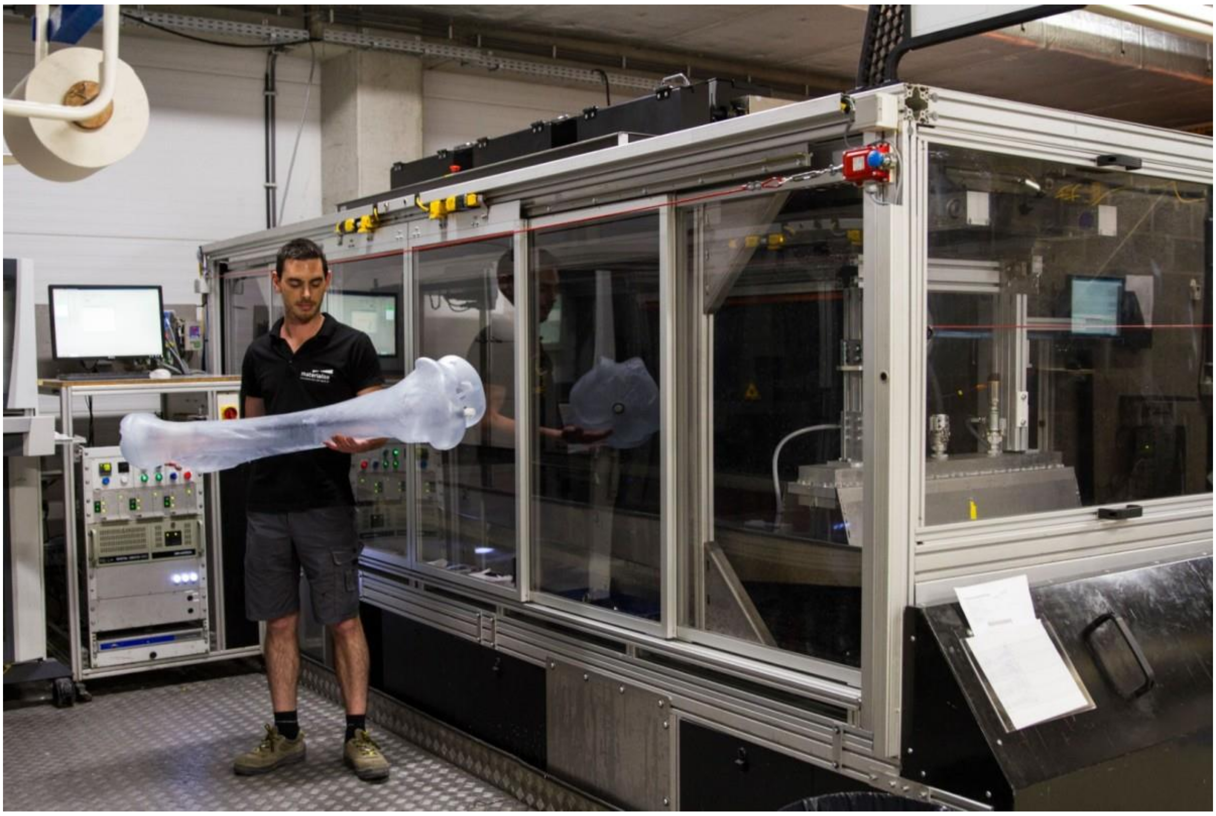

Figure 4. One of the 3D-printed mammoth bones, alongside one of the Mammoth Stereolithography large-format printers (Retrieved from: https://newatlas.com/materialise-3d-printed-mammoth/57026/)

Additionally, in the Burke Museum in the USA, a similar project was created. With the help of the University of Washington, the skeleton of a mammoth with 20% of the real fossil parts was created. For a reconstruction of the actual Columbian mammoth, previously scanned and 3D printed parts, as well as scanned and scaled bones from other mammoths, were used. (“Starting to 3D print the mammoth”, 2017)

3D maps

An alternative way of presenting science with the help of 3D printing can be done via 3D printed maps. Physical maps in three dimensions can be helpful for visually impaired people as these types of maps can be studied with an impact on other senses. (Chua & Leong, 2017) In comparison with classic paper maps, the interaction with 3D map models is simple and more intuitive and easier to learn. (Giraud et al., 2017)

Mathematics

To present more possibilities of popularization of science the printing of teaching aids should be mentioned. The possibility of printing missing aids or design specialised aids depending on a chosen subject can be a great help. Presenting hardly imaginable concepts with the help of 3D printed subjects can prove to be very useful for the comprehension of various phenomena. To provide an example, Segerman in his book called Visualizing Mathematics with 3D Printing describes the possibility of experiencing three-dimensional subjects directly. Even up to present how we can project four-dimensional objects by casting its shadows back to the three dimensions. (Segerman, 2016)

TEDTalks

An additional option of presenting 3D printing can be when scientists created human tissues with the help of 3D printers and further presented their work via TED talks conference. (Atala, 2011) This act can be acknowledged as popularization of biology and medicine due to scientists taking a different approach of creating human tissues while presenting their research and results on a very well-known and recognized platform.

5.2.3 Use of 3D printers in various institutions

As it was mentioned in the previous chapters, 3D printers can be used for popularization of science in a way of printing specific objects. In comparison with the previous chapter, which was more focused onto the printed objects, this subchapter will be more focused on institutions where the 3D printers can be actually used by the visitors.

3D printers in schools and libraries

The usage of 3D printers in schools, libraries or even its integration in classes can make 3D printers easily approachable thus more popular and easily utilized. In this case, 3D printing can serve for popularization of the science subject taught, as well as, the integration of 3D printing in class can lead to the popularization of its technology. Some possible approaches to the use of 3D printers in school libraries were proposed by L. M. Cano. 3D printers can be used to aid with increasing vocabulary, analysing poetry, understanding prefixes and suffixes, evaluating sources, as well as, to create visual models or book covers. (Cano, 2015)

Alternatively to 3D printers, 3D printing pens can be used as a teaching aid. To provide an example, a 3D pen can be used in learning mathematics, where the students can use 3D modelling pens for better understanding functions and calculus. (Ng & Sinclair, 2018)

Another example can serve the use of 3D pens chemistry for drawing of molecular models in 3D. (Bernard & Mendez, 2020)

The use of 3D printers in VIDA! Moravian Science Centre Brno

In this thesis VIDA! Moravian Science Centre Brno was questioned about the approach to the use of 3D printers, as 3D printers in this institution are displayed for the visitors to see and the machines themselves were already previously engaged in children club activities. The approach to 3D printing can be different in any other science centre or place intended for science popularization.

VIDA! Science centre defined on its website vida.cz states as following "Near the Brno trade fair complex, playful explorers of all ages will find more than one hundred and seventy interactive exhibits over an area of nearly 6200 square meters that will give them a better understanding of the world around us." (*WHAT IS VIDA!?*, n.d.) VIDA! Moravian Science Centre Brno can be seen as a form museum where the visitors are encouraged to test and manipulate with the exhibits for the experience of discovering. The main purpose of VIDA! Moravian Science Centre Brno is to popularize science. It is not solely focused onto the exhibits discoveries, shows about science, movies in 3D and other creative activities are also offered to visitors.

The information concerning VIDA! Moravian Science Centre Brno below were obtained in the form of an interview with an employee in charge of 3D printers on 16.4.2020 and afterwards translated into English. Official English names of the exhibits or programmes were found on the official website vida.cz.

Concerning the 3D printers, firstly, the factual information should be provided. Three 3D printers from TRILAB (M, L) and one from Prusa3D (Prusa i3 MK3) are displayed in VIDA! Moravian Science Centre Brno. The filament types commonly used there are PLA, FLEX and PET (PET was also used for printing of parts, more specifically holders for protective shields, during the coronavirus outbreak as this material should be easily sterilised).

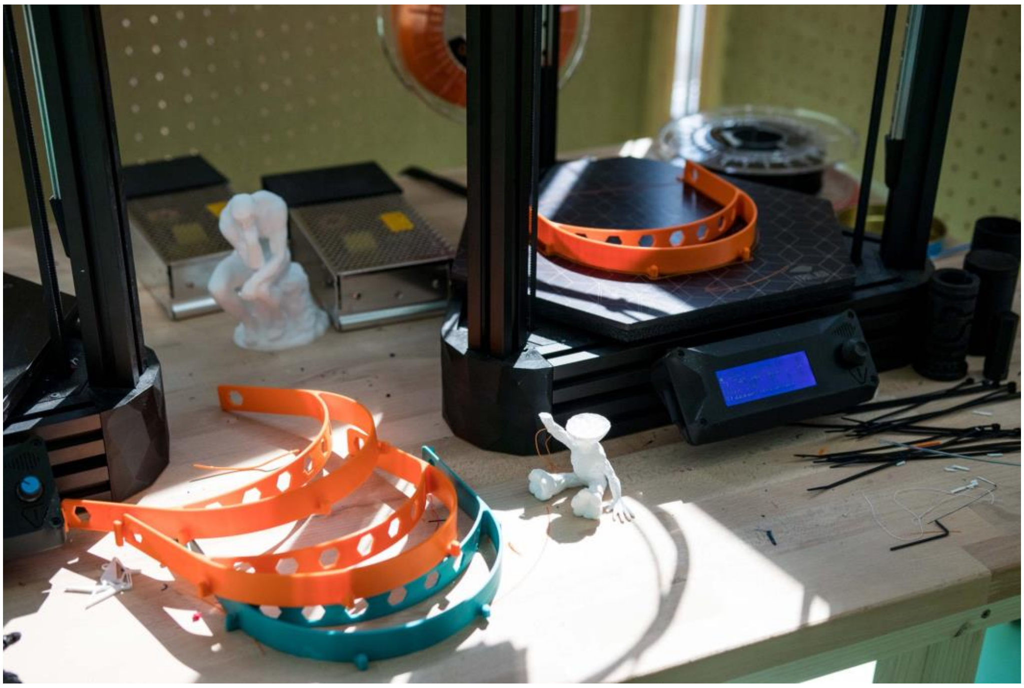

Figure 5. Protective shield holders printed from VIDA science centrum (Retrieved from: https://www.facebook.com/photo?fbid=3132756326776348&set=a.3132755020109812)

The use of 3D printers by this science centre can be for better comprehension arranged into three categories.

Firstly, 3D printers are used to print parts used for repairing exhibits such as glass eyeball or fog (official names of exhibits were taken from vida.cz webpage). (*VIDA! EXHIBITION*, n.d.) The printers are also used to create tools for VIDA's educational programmes for schools (for example a model of the clitoris for a programme concerning the human body or human hearts in the life-size and its miniature version as properties for vision-impaired people).

Secondly, the 3D printers themselves are located in "Bastlírna", which is an open space located at the end of exposition serving for visitors do-it-yourself projects. (*BASTLÍRNA,* n.d.) As the interaction of visitors with 3D printers would be demanding and lengthy, 3D printers currently serve as a form of presentation of the technology. Formerly, small components for "Bastlírna" were also printed there, however, this approach did not meet success and was abandoned. The 3D printers located in "Bastlírna" arose many questions among visitors. Most frequently asked questions were: the duration of printing, the price of a printed object and rarely the whole process of printing (this question was focused to obtain a form of instructions on how to operate a 3D printer).

Thirdly and most importantly in connection with this subchapter, 3D printers were one of the technologies used during an afterschool activities club for children attending 6th or 7th grade of primary school called “Bastlkroužek”. (*BASTLKROUŽEK,* n.d.) This club was mainly focused on technologies used for creating and do-it-yourself activities. Preceding the practical 3D procreation children were shown 3D scans and 3D printers of various sizes with diverse filaments placed in FABLab truck. Afterwards, children could design their name tags onto a predefined mat. For the process of designing children were provided with tablets and TinkerCAD. The subsequent task for children was to design pen holders. This task was less strict, not excessively specified, which meant that the form of processing was mainly for the children to decide. This led to the final pen holders to be more decorative and ornamental than functional or useful. For the stated age group it was easier to work on a less specified task. The diversity of the quality of the final products was huge, even though the children were of a similar age.

6. Practical part

In this chapter ideas for activities with the use of 3D printing will be proposed. The aim of these activities is to acquaint the public with 3D printers and 3D printing pens. This chapter is divided into three subchapters each focused on a specific part connected with 3D printing. Firstly, the communication of theoretical background will be presented, following with chapter proposing specific activities for 3D printing pen creating and lastly, chapter mainly focused on work with 3D modelling software. For each activity the main objective of that specific activity will be determined, as well as, expected time requirements, material requirements and the target age presumed. These requirements were chosen based on personal experience and are considered relevant and important when creating specific activities.

The form of communicating the information

The form of communicating the information plays an immense role in understanding as well as in awakening an interest in the specific topic. Thus it is important to use appropriate language, set adequate time for presenting and use aids for the explanation. For disclosing the facts, most preferably popular scientific language should be chosen. All the necessary scientific or technical terminology used needs its explanation. If it is possible, the approach of presenting the information visually should be used with the aim of popularizing. The practical usage serving as an illustration can lead to easier understanding of the printing process. When delivering a piece of information, it is important to interconnect all the transmitting knowledge and aspire to achieve the unity of the message. In short, expression of the whole is more preferable than the communication of parts only. The use of simplification or comparison to everyday activities can lead to a better perception of a complicated phenomenon. The complex information can be explained with the help of something well known and easily understood by the listener. The interest of the listeners when communicating new information should be aroused, so the receiver will be interested in the topic even after the “event” itself ends (e.g. search more info at home). Last but not least, it is meaningful to decide the time range beforehand, take in consideration the listeners concentration span, for how long the receivers will be able to concentrate on the communicated information.

6.1 Theoretical background

The preceding theoretical knowledge is important for the subsequent practical activities. The possible problems and dangers of working with the technology should be known, so they can be avoided or at least minimized during the practical manipulation.

6.1.1 Process of printing with FFF/FDM printers

Objective of the activity: The main aim is to present the theoretical background of 3D printers using Fused Filament Fabrication (Fused Deposition Modelling) techniques to children without any previous knowledge. Children should be able to understand the process of 3D printing from its origin till the final product and express it in their own words, as well as, describe 3D printer's structure. The theory should be a prerequisite for following practical activities.

Material requirements: Visual aids, most preferably 3D printer in operation, or PowerPoint presentation containing pictures or short videos.

Expected duration: 40minutes

Target age group: 11 to 14 years

Description of the activity:

At first, the printer itself should be presented. Most preferably the printer directly in operation, however a picture or a video of the printer is also an option. During the explication of 3D printing questions should be asked and answered, leading to a discussion.

1. What has to be done before an object is fully 3D printed?

Firstly, a model for 3D for printing has to be created. You can design one by yourself, use a 3D scanner for scanning an object to be recreated or use publicly available models. If you want to design a 3D model by yourself you have to keep in mind a few rules. The object should not have any parts which are overhanging in more than 45° angle without a support.

How do I know if it is more than 45°angle? Try to guess from these pictures if they need any support structure, if yes determine where. Each picture should lead to discussion about the best position of the model to the printing bed and parts which are in need of support. (The subsequent pictures are a personal suggestion and do not have to be exactly followed, any other pictures can be used.)

Picture showing the rule previously described:

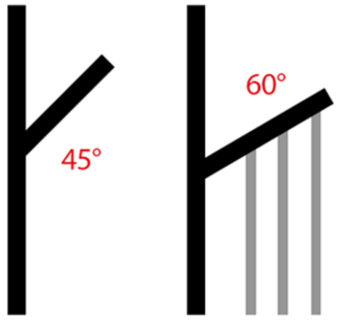

Figure 6. How much is an angle of 45°? (Retrieved from: https://www.dddrop.com/3d-printing-tip-printing-with-support-material/)

- Does letter T need any support? Would repositioning help us?

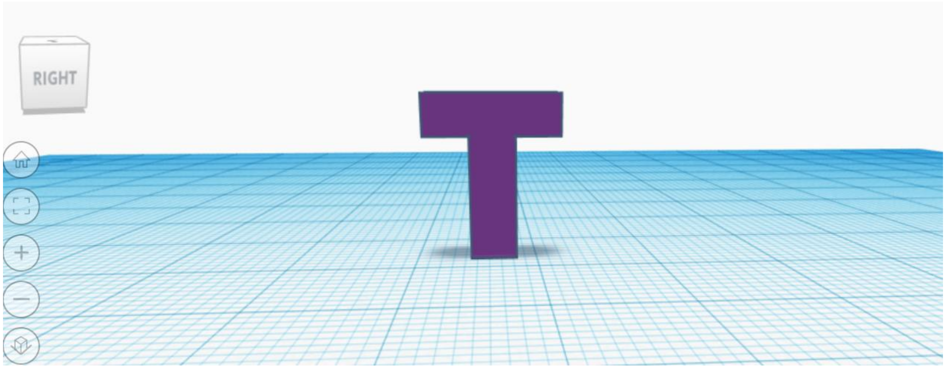

Figure 7. Letter T in 3D (created in Tinkercad: https://www.tinkercad.com/)

- Does letter Y need any support? Would repositioning help us?

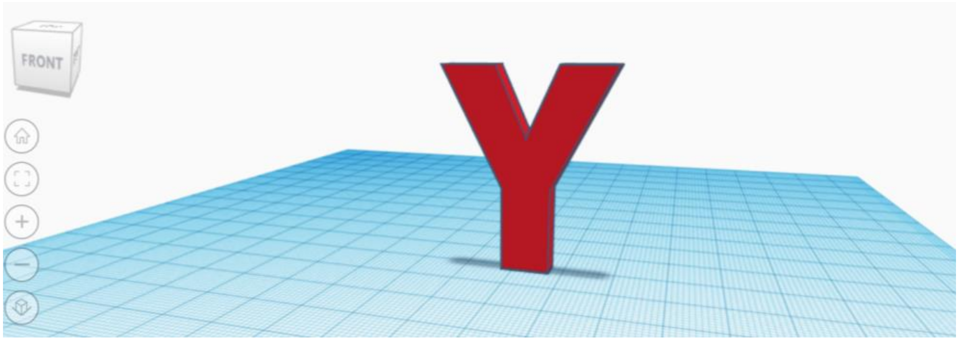

Figure 8. Letter Y in 3D (created in Tinkercad: https://www.tinkercad.com/)

Figure 9. Solution of the support structures (Retrieved from: https://all3dp.com/1/3d-printing-support-structures/)

- Would this model of *"Kevin Killerwhale"* by Steven Flammia need any support? Would repositioning help?

Figure 10. Kevin Killerwhale by Steven Flammia (Retrieved from: https://www.tinkercad.com/things/ctIiv3AmFq0)

In some of those models, the support structures can be fully omitted after a correct change in its orientation on the printing bed.

After the design is fully modelled and the model is certain to be in a 3D printable format, it goes for slicing and can be sent for printing. After the object is 3D printed it should be removed from the printing bed, as well as, it should be cleaned from all excess material.

2. How does Fused Filament Fabrication/ Fused Deposition Modelling printer work?

Most likely anyone can get into contact with FDM printers. It is stated that *"As of 2020, the most commonly used 3D printing technology was fused deposition modelling."* (Most used 3D printing technologies 2020, 2020)

These printers work by adding molten plastic in layer by layer until piled up into the desired shape. These 3D printers consist of the basic parts which can be seen in the figure below.

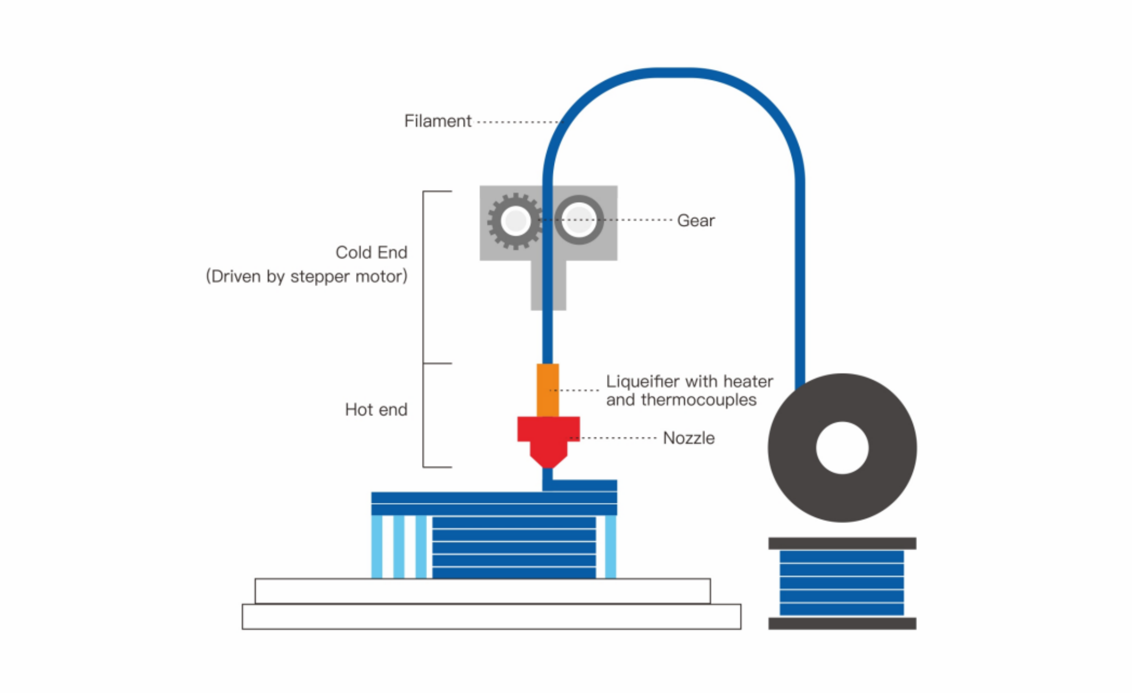

Figure 11. FFF 3D Printer work diagram (Retrieved from: https://creality.com/info/everything-that-you-can-get-about-the-3d-printer-extruder-i00126i1.html)

6.1.2 3D printing with 3D pens

Objective of the activity: Present another possibility to 3D printing, the use of 3D pens

Material requirements: Visual aids, most preferably 3D pen, PowerPoint presentation containing pictures and short videos.

Expected duration: 30minutes

Target age group: 11 to 14 years

Description of the activity:

At first, present a 3D pen as another possibility for printing to 3D printers. If possible pass the pen to the listeners for closer look and possible touch, if this is not possible, show the pen on a picture. Then describe the process of pens operation while describing each part of the pen separately.

Figure 12. 3D printing pen with description (Retrieved from: https://verysmartgadget.com/nextech-3d-printing-pen-review/)

First starting from the top of the pen differentiating between a hole for the filament input and the power source hole. On the body of the 3D printing pen should be buttons for temperature control, so the temperature can be increased or lowered. These buttons are important when using different filament materials as each material has its own melting temperature. Additionally there should be buttons adjusting speed of the filament extrusion. By controlling the speed of the filament extrusion the thickness of the drawings can be adjusted. Furthermore, buttons for filament loading and unloading should be present on the device as well. When changing filament for another colour, the unload button is used. It is important to keep in mind that the previous colour combines with the newly filled one creating excess material of unwanted colour. Last but not least, the 3D pen nozzle, where the molten plastic is leaving the pen. The security of working with a 3D pen should be emphasized, as injuries can occur due to high temperature of the nozzle as well as the material. Furthermore, 3D pens do not cool down immediately after they are turned off. It takes some time to cool down the nozzle, similarly as in glue guns.

6.2 3D pens

First activities when using a 3D printing pen should be easily feasible. If the first activities with 3D pen are disproportionately complicated to perform, the initial disappointment can lead to discouragement for further efforts.

6.2.1 Connecting 2D objects into 3D object

Objective of the activity: Learn the possibilities in operation of 3D printing pen. Create 2D objects and connect them to create a 3D object.

Material requirements: 3D printing pen, small sheet of paper, wax or parchment paper (to be used as a mat), filament, scissors, paper templates

Expected duration: 30minutes

Target age group: 11 to 14 years

Description of the activity:

Children will be encouraged to draw anything they would like, on a piece of paper and afterwards recreate it by drawing with 3D pen onto wax paper over the paper. (For beginner users it is better to use wax paper or parchment paper as they are resistant to high temperatures, in comparison with regular paper or other types of mats.) The drawing will be on the wax paper at this moment. When finished the filament should be peeled off the paper. When peeling the filament of the paper some pieces (which are not connected) can stay on the paper. This way children will realise that all the lines have to be connected. After peeling the filament, the drawing can be connected by 3D pen onto a 3D printed base. (If the children have no creative ideas after few minutes, they can be provided with a pre-printed templates, simple pictures on a paper)

6.2.2 Possibilities of drawing in space

Objective of the activity: Creatively use the 3D printing pen in space. (Geometric ornaments: a cube, a cuboid, a pyramid and other possible shapes)

Material requirements: 3D printing pen, filament, scissors, mat (a sheet of paper a wax paper can be used as a mat), wooden skewers

Expected duration: 30 minutes

Target age group: 11 to 14 years

Description of the activity:

Let children draw anything into a space. Most likely they will be able to create some kind of springs or piles of filament. Give away wooden skewers, and ask them to create a pyramid or other shapes in the space. With the help of wooden skewers or other prompts, they should be able, after some time, create straight lines in the air and connect them into pyramids.s

6.2.3 Creating personal phone case

Objective of the activity: Think creatively in connection with useful products

Material requirements: 3D printing pen, filament, paper, mat (wax paper can be used as a mat)

Expected duration: 2hours

Target age group: 11 to 14 years

Description of the activity:

Ask the group to design their personal phone cases. First draw the shape of a personal phone onto a paper. Put wax paper over the drawing. Redraw by 3D printing pen and let children be creative when designing a phone cover. In the next step measure the height of the phone and add 3rd dimension to the phone cover around the edges, so the final product will serve as the phone cover.

6.2.4 Simplified density cubes

Objective of the activity: Create 3D cubes of the same size with various amounts of filament used. Understand the concept of density.

Material requirements: 3D printing pen, mat (sheet of paper can be used as a mat), filament

Expected duration: 2hours

Target age group: 11 to 14 years

Description of the activity:

Every child will create its own cube of the same designated size. From each individual different amount of the filament used for this creation is expected, which means that each cube should be of the same size but different in the density of filament. The final modelled cubes will be used for demonstration of the density in the tank of water, where each of the cubes should push out different amounts of water (equivalent to its own density).

6.2.5 Possible problems during aforementioned activities

When working with 3D printing pens, various problems may occur. In the first place, there is possible danger of burn injuries due to the high temperature of outcoming filament and the nozzle. Additionally, material used for 3D pens has to be chosen carefully. The most suitable filament depends on the exact space where the activity will be executed. To be more specific, a small closed room without good ventilation PLA would be a better material choice, due to its lower production of fumes in comparison with ABS. However, this material has its own disadvantages which needs to be taken into the account before use.

Other problems, which are not connected with health, can be high expectations for the first product, leading to disappointment. It is important at first to learn how to use a 3D pen as a first-time user may cause many beginner mistakes. For example, during the first operation with a 3D pen the user can extrude too much filament, not enough filament, too fast strokes or try drawing in space without any base aid. Additionally, when using a 3D pen to connect previously printed and already solid parts can lead to melting of nearby surroundings due to high temperature of extruded filament for connection.

6.3 3D modelling

The choice of 3D modelling software should be based on the final product expected. As it was mentioned in the theoretical part, there exist numerous approaches to the object modelling, as well as, for each approach exist many programs which are easily manageable, for free, and without any higher requirement onto the computer performance.

It is also possible to create the model with the help of 3D scanners, however 3D scanners are predominantly very expensive. There is an option to create a reconstruction of a 3D object from its photos with a technology of a photogrammetry. Although, this process tends to be lengthy and does not present high quality results.

Nevertheless, if the most important part of the process is simply to see a 3D printer in its movement, it is not necessary to spend a long time designing your own model as there is an option of downloading 3D models. Many sites and archives offer various 3D printable models freely available to the public or for a fee.

Choosing the most suitable program for modelling

Prior to the process of 3D modelling the most suitable program should be chosen meeting the specific needs. Some of the highly suitable programs are proposed below, mentioning their benefits for the inexperienced user.

Tinkercad is a solid modelling type of software, offering a wide range of predefined structures to use (basic shapes, letters, numbers, connectors and other special shapes). This means that this modelling technique is more intuitive for beginners. Moreover, educational resources in a form of tutorials are available for Tinkercad, where all the base ideas are explained, thus it is easy to learn the basic concepts of 3D modelling. Additionally, Tinkercad provides the models created for use and modifications. (Tinkercad, 2019) For the practical part of this thesis this program was chosen as the most suitable and easily usable.

Meshmixer is another modelling program which can be also used for a clean-up of 3D scans. This program offers automatic orientation of the model on the printing bed. Also it can generate support structures for the model. Additionally, its function of "Robust Convert-to-Solid" aids with the preparation of the model for the 3D printer. (Autodesk Meshmixer, 2017)

Leopoly is closer to a digital sculpting program, which proposes more artistic features. This program works similarly to modelling with clay by adding and removal of material from a prepared base. Except for 3D printing or 3D scanning, this software is focused on creating Augmented Reality (AR) and Virtual Reality (VR). This program is also browser based. (Leopoly, 2019)

6.3.1 Creating a nametag in Tinkercad

Objective of the activity: Create a 3D name tag in Tinkercad

Material requirements: computer or tablet with connection to the internet, Tinkercad account

Expected duration: 15min

Target age group: 8 to 12 years

Description of the activity:

Create a personal name tag in Tinkercad. Create a new design of a nametag in Tinkercad by modifying basic shapes (in this exact scenario Box and RoundRoof) and adding text onto the base. Similarly, in one of the Tinkercad's tutorials is to create keychain with a name.

Possible outcome:

Figure 13. Nametag KLARA 3D model (created in Tinkercad: https://www.tinkercad.com/)

6.3.2 Modelling of a car in Tinkercad

Objective of the activity: Create a 3D car in Tinkercad

Material requirements: computer or tablet with connection to the internet, Tinkercad account

Expected duration: 40minutes

Target age group: 8 to 12 years

Description of the activity:

Design a 3D model of car by using simple shapes in Tinkercad. The most simple car can be created by combination of Boxes and Cylinders. Depending on each of the child's skills, the car designs may vary from the simplest to more elaborated designs.

Possible outcome:

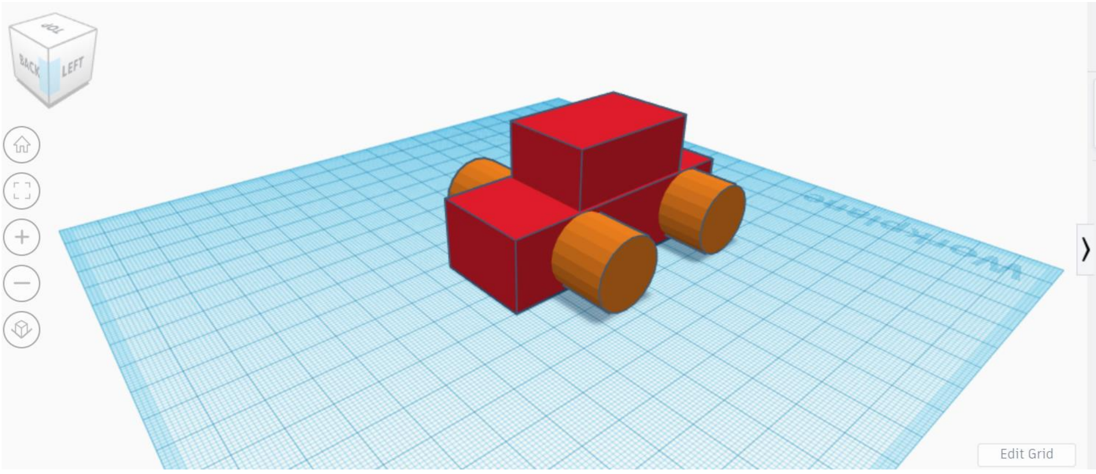

Figure 14. Simple car 3D model (created in Tinkercad: https://www.tinkercad.com/)

6.3.3 Modelling of a teddy bear in Tinkercad

Objective of the activity: Create a 3D teddy bear in Tinkercad

Material requirements: computer or tablet with connection to the internet, Tinkercad account

Expected duration: 40minutes

Target age group: 8 to 12 years

Description of the activity:

Design a 3D model of a teddy bear by combining simple shapes which are available in Tinkercad. The most simple teddy bear can be created from a combination of Spheres and Half Spheres. Depending on each child's skills and creativity the final designs can differ as some of them may be simple to and others can be more detailed.

Possible outcome:

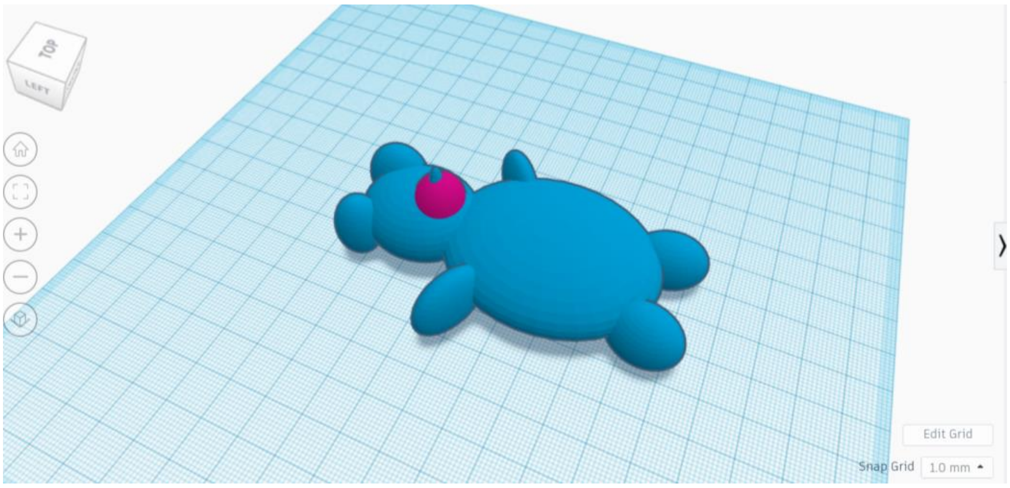

Figure 15. Simple 3D model of a teddy bear (created in Tinkercad: https://www.tinkercad.com/)

When the 3D models are printed it is possible to additionally decorate them by 3D printing pens.

6.3.4 Realisation of activities

During the realisation of aforementioned activities can occur problems connected with the malfunction of necessary devices (computer, tablet) or internet disconnection can occur. Simple objects were proposed for children activities to design as more useful objects may require a deeper previous knowledge and more time. These activities which were proposed are adjusted to the time length of club activities which most likely last one hour.

6.4 Outcomes of the practical part

Proposed activities are realisable mostly in a form of independent activities for the first contact with 3D printing. Some of the activities with 3D printing pens were supposed to be realised at the beginning of May, however due to covid-19 outbreak the implementation did not take place at that time.

The activities proposed may be utilized in this form or after modification in the approach to their presenting. The proposed time for activities is not strict, thus could be modified for the group needs. Additionally, these activities can be taken as first activities in connection with 3D printing. In the future, they can be completed with more advanced activities and create a complete program of activities for children’s clubs during the year.

7. Conclusion

Modern technologies in lead with 3D printing became known to the wide public now more than ever. The understanding of modern technologies may be beneficial even for the quality of life. The modern 3D printers are becoming less expensive and easier utilizable than before. The use of 3D printers can lead a step closer to the personalization of common objects. Subsequently, 3D printers can encourage creativity, as they can transform one's imagination into physical objects.

In the theoretical part of this thesis the terms like 3 Dimensional Printing, Rapid Prototyping and Additive Manufacturing, which are directly connected with the 3D printing, were defined and differentiated. Although, the terms are different, they do convey similar meanings. The whole process leading to the 3D printed object is described, as well as, the history of 3D printing invention. Moreover, the 3D printing pen is mentioned as a device based on 3D printing technology. It provides a possibility of drawing in 3 dimensions. Different types of 3D pens and common types of filament used by hot 3D pens are introduced. Furthermore, the approach to use 3D printers is mentioned. 3D printers utilization in the science popularization facility VIDA! Moravian Science Centre Brno are described. Possible usages of 3D printers with the purpose of delivering insight into various scientific fields are stated. As examples, the printing of skeletons in museums, 3D printed teaching aids or sharing the knowledge about possible inventions with 3D printers via TEDtalks are mentioned apart from others.

The practical part is further divided into three main subchapters - theoretical knowledge, 3D pens and 3D modelling. Each subchapter proposes specific and different approach. All of these activities are proposed for a group of children as its target group. Firstly, the approach of presenting the theory in a more enjoyable form is proposed for 3D printing and 3D printing pen technology. In the following part, are proposed activities working directly with 3D printing pens, which should lead to more comfortable utilization. In the following subchapter, the emphasis is put onto modelling with 3D modelling programmes. From programmes mentioned in the theoretical part are selected some of the most interesting with its specific benefits for the utilization. The activities are proposed for one of the mentioned programs, Tinkercad. With this program are introduced specific activities where children should be designing simple decorative objects.

The overall timing of the activities may vary depending on its working group specification, on the skills of children and many other factors which are not easily influenceable or predictable. However, in continuous practical use of those activities, the presenting person may be able to modify problematic parts of activities or find approaches to fasten children's working process avoiding spoiling the child's experience. Although, this is not to be theoretically proposed and should be practiced with an actual group of children.

The main focus of this thesis is put onto the use of 3D printing by an unprofessional public which is not acquainted with the technology. More precisely, it intends to propose various ways to present 3D printing technology and educate children in a more enjoyable and fun form. It is highly important to introduce technology in comprehensible means to children so they would not be afraid to try and learn new technologies by themselves. Additionally, this can serve as a motivational factor in the future choice of occupation. The knowledge of 3D printing may be beneficial to them in the future even if they do not choose it as the main study interest. 3D printing seems to be a fast-developing technology with possible use in everyday life. Additionally, 3D printing might be the future of more ecological alternatives to mass-produced objects. Hopefully, this approach could be more motivational towards children's further discoveries. In the end, one can only hope this thesis to achieve, at least partly, its main purpose.

Rozšířený abstrakt

Tato bakalářská práce se zaměřuje na využití 3D tisku veřejností, která není s touto technologií seznámena. Technologie 3D tisku byla primárně spojována se strojním inženýrstvím, avšak dnes je známá i pro širší veřejnost. Svou popularitu si získal 3D tisk v oblasti medicíny, v leteckém průmyslu, v architektuře, ale i v módním průmyslu nebo v oblasti šperkařství. Jako zajímavost ve využití 3D tisku může být zmíněn například 3D tisk z čokolády. Moderní 3D tiskárny jsou výrazně dostupnější a často i snadněji ovladatelné než jejich předchůdci, dokonce i pro neodbornou veřejnost. Hlavním cílem této práce je obeznámit čtenáře s principy 3D tisku a jeho možným využitím pro popularizaci vědy, se zaměřením na návrh aktivit kroužku pro děti.

Tato práce je rozdělena do dvou hlavních částí – první část formou rešerše seznamuje čtenáře s teorií a druhá část předkládá návrhy na praktické aktivity realizovatelné součástí kroužku pro děti.

V první části je nejprve definovaná terminologie spojená s 3D tiskem. Dále je v práci popsán proces 3D tisku od návrhu 3D tisknutelného modelu až po finální opracování vytištěného objektu. Při procesu 3D tisku je potřeba u určitých typů tisku dbát na pravidlo úhlu 45°, které udává že jakýkoliv převis modelu, který je menší než 45° vyžaduje podpěru pro správné vytištění. Před vytištěním modelu je potřeba se nejprve ujistit o jeho jednotnosti a dále jej rozdělit do tenkých horizontálních průřezů. V rámci popisu tohoto postupu jsou 3D tiskárny rozděleny do kategorií podle vstupního materiálu. V této úvodní části je také nastíněn historický vývoj 3D tisku od vynálezu technologie Stereolitografie až po rozvoj projektu RepRap. Nejznámější techniky 3D tisku jsou také uvedeny v přehledné tabulce.

Kromě již zmíněných informací k 3D tisku jsou v práci také popsána 3D pera, neboli 3D tisková pera. Tato pera jsou popsána z hlediska technologie, na které jsou založena, na horká a studená 3D pera. Vhodné materiály pro horká 3D pera jsou též zmíněny.

Nejen samotný 3D tisk je vylíčen v první části této práce, i proces tvorby 3D tisknutelného modelu je popsán. Modely mohou být vytvořeny pomocí různých typů 3D modelovacích programů nebo s pomocí 3D skenerů.

Možnosti využití 3D tiskáren a 3D per jsou popsány a to se zaměřením na popularizaci technologie 3D tisku, nebo jako nástroj, který je možné využít za účelem popularizace vědy. Jako příklad popularizace technologie 3D tisku je v práci zmíněn projekt Rep Rap. Tisk kostry mamuta a tisk 3D map jsou zmíněny jako příklady, kdy je 3D tisk s využit pro popularizaci určitých vědeckých disciplín. Koncem teoretické části práce je dále zmíněno využití v různých institucích se záměrem popularizace.

V druhé části, která je částí praktickou, jsou navrženy potenciálně využitelné aktivity pro děti s cílem vzbudit zájem o technologii a motivovat pro další objevování a poznávání. Praktická část je dále rozdělena do tří podkapitol zaměřujících se na sdělení teorie, na práci s 3D perem a na návrh 3D tisknutelného modelu. Veškeré tyto aktivity obsahují hlavní sdělení aktivity, potřebný materiál na uvedení aktivity, očekávanou délku trvání, věkovou skupinu na kterou je daná aktivita zaměřena a popis aktivity.

V první pod části, zaměřené na sdělování teorie, je navrhnut způsob prezentování procesu 3D tisku technologií FDM (Fused Deposition Modelling) a všeho co tisku předchází, například důležité generování podpěr. Dále je zde navrhnut i možný způsob prezentování technologie 3D per.

Druhá pod část je zaměřená na návrh aktivit s použitím 3D s cílem předejít prvotnímu zklamání z nepovedených výtvorů. Navržené aktivity jsou zaměřeny na kreslení 3D perem na podložku a následné spojení do prostorového objektu, vyzkoušení si kreslení 3D perem do prostoru, tvorba obalu na mobilní telefon nebo tisk krychlí stejných rozměrů s různými objemy. K těmto aktivitám jsou dále popsány problémy které mohou nastat v průběhu jejich vykonávání.

Jako třetí, poslední pod část praktické části, je zmíněno 3D modelování. Využití 3D skenování pro tvorbu aktivit nebylo věnováno velké množství pozornosti z důvodu vysoké pořizovací ceny 3D skenerů a také kvůli značným požadavkům na výkon počítače při realizaci modelu. 3D modelovací program by měl být zvolen podle očekávaného finálního produktu a jeho potřeb. Pro tuto část byly navrhnuty tři programy, které jsou vhodné pro nezkušené začátečníky. Jako důležité vlastnosti programu byly zmíněny především intuitivnost, jednoduchá orientace práce v programu, a pokud možno nízká cena. V návrhu aktivit byl nakonec využit pro návrh 3D tisknutelných modelů program Tinkercad. Zvolené objekty pro modelování jsou jednoduše představitelné a dekorativní. Aktivity zmíněny v této části jsou například modelování jmenovky, tvorba 3D modelu auta nebo tvorba 3D modelu medvídka. Součástí těchto aktivit jsou též možné výstupy ve formě vytvořených 3D modelů.

Výstupem této praktické části jsou samostatné aktivity určené pro seznámení se s 3D tiskem. Veškeré tyto aktivity mohou být dále použity v navrhované formě nebo pozměněny například ve formě uvedení. Čas navržený na jejich realizaci se může dále měnit dle schopností skupiny i jednotlivců.

Tato práce může dále sloužit jako podklad pro tvorbu podobných aktivit, popřípadě být zakomponována do dlouhodobějších aktivit kroužku. Navržené činnosti mají za cíl vzdělávat a přiblížit technologii 3D tisku zábavnou formou a tím pádem také motivovat k dalším možným objevům.

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